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Long time measurements of noise from wind turbines

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Abstract

Noise is an important environmental factor at windmill sites and hence there is a need for reliable methods to control the exposure situation. It is difficult and time consuming to make field measurements that cover a large variety of metrological situations. A measurement station for long time noise measurements have been developed which makes it possible to make noise registrations and recordings at different weather situations.
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1. Background

The demand for alternative energy sources has lead to a large extension of the number of wind turbine sites. In Sweden, the number of larger plants is 620 with an installed power of 345 MW. Today the trend moves towards larger turbines and the mean power rating for new plants in Sweden are 862 kWh. Since the sites often are located in rural areas, conflicts with the recreational life often occur [1].

The two main environmental aspects of the wind turbines are the visual impact on the landscape and the noise emission. The dominating noise source in modern wind turbines is aerodynamic. This noise is generated when the blades pass the air at high speed and it has a broadband sound spectrum. The other noise source is the mechanical system, which generates sounds that can be heard from some wind turbines. As noise is a significant annoyance factor in

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the environment it is important to have good prediction models for new plants and reliable methods to control the noise situation in existing situations. The prediction models used today are often based on a fixed meteorological situation. It is difficult and time consuming to make field measurements that cover a large variety of meterological situations.

2. Method

To make long-term measurement at different sites and during a wide range of meterological situations, a measurement station has been developed and used at our department. The following specifications of requirements were demanded:

The system should be remotely controlled with data logging for time periods up to several weeks. The system should be able to continuously measure wind direction, speed, temperature, humidity and precipitation. The wind anemometer should be positioned at the height of 10 m above ground. Sound level and statistical units should be continuously stored for later analysis. Spectral analysis of recorded noise should be done at relevant wind conditions for later analysis. These demands were fulfilled using the following equipment and technique.

For the acoustical measurement, a 1/2 inch measurement microphone was used (Brüel&Kjœr type 4190). The microphone was attached firmly on a vertical 1 m^2 hardboard. The board was perpendicularly facing the sound source. This method is described in the following documents [2,3]. The sound level measured on the reflecting plane was later corrected with -6 dB to represent the free field value. As wind protection a halved foam windscreen was used over the microphone. In addition, a spherical screen with wool clothing with a diameter of 40 cm was placed above the arrangement. See Fig. 1.

The microphone was connected via a preamplifier to a microphone conditioning amplifier Brüel&Kjœr Nexus type 2690. The logging of A-weighted sound level and statistical analysis in

Fig. 1. Picture showing the microphone arrangement without the windscreens.

Fig. 2. Picture showing the mobile caravan and meterological mast.

units as L_{01}, L_{10} and L_{90} was done using a sound level meter from Larson&Davis type 820. For later spectral analysis, recordings were done on a digital audiotape recorder (Sony TCD-D8 DAT). The recorder was remotely controlled in such away that the recorder was triggered manually via an interface and cellular phone modem described later. Hard disc recordings were first planned but due to slow phone modem data link and lack of hard disk space recordings had to be picked up manually via the DAT-tape.

For the meterological measurement and data logging, a Davis Weather Monitor type II was used with the wind anemometer placed on a 10 m telescopic mast. Data from the weather station were stored as mean values based on 10 min periods. Both the weather and acoustical station was computer controlled and this computer was remotely controlled using the software (Symantec PCAnywhere 9.0) via a cellular phone modem. Measurement data were downloaded at regular intervals and after special attention indicated by local weather forecast or observations at the weather station tape recordings were triggered.

All equipment was housed in a mobile caravan that could be parked at different locations and distances relative to the wind at the current turbine site. The arrangement gave great flexibility in investigating the influence of different factors such as ground attenuation, wind direction and other meterological parameters on sound generations. The degree of background noise level could also be systematically surveyed (Fig. 2).

3. Results

The system has been used for 2 years at many different locations and has given valuable information regarding the noise situation and propagation at several different wind turbine sites in southern parts of Sweden. The measured field data have been compared with the theoretical calculation models and the influence of different meteorological situations has also been studied.

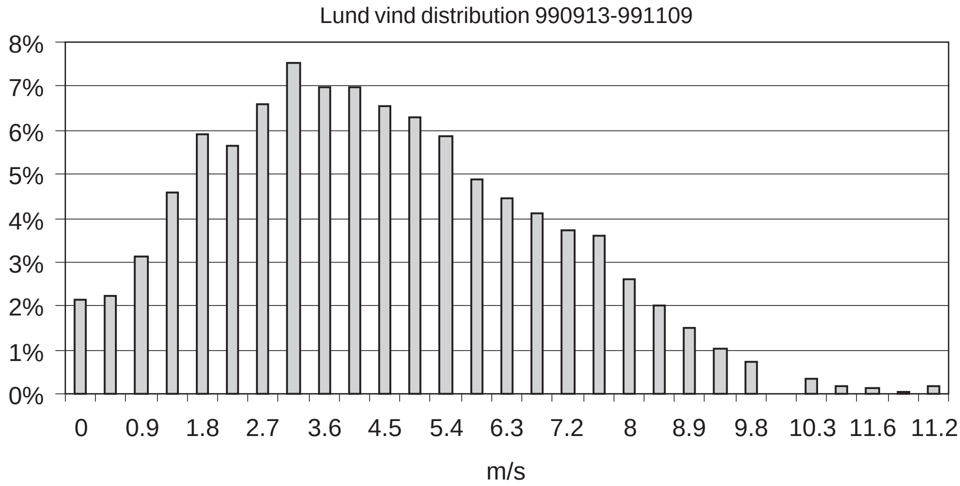

Fig. 3. The wind speed distribution, percent of total measurement time.

The recorded sounds from different wind turbine types will be used for later evaluations in the noise laboratory.

Since the data base of measurement results are rather large, the following presentation can only reflect some more general findings that are of value for the understanding and planning of field measurements.

Fig. 3 shows the distribution of wind speed at a typical wind turbine at a rural site in southern part of Sweden (Lund). The measurement period at this wind turbine was 8 weeks during autumn (September–October). The histogram shows that a wind speed of 8 m/s or more, only occurred during 2.5% of the total measuring time. The preferred wind speed is 8 m/s for noise emission classification in Sweden.

Another important factor is the wind direction relative to the turbine and the receiving point. The highest noise levels are usually found in the down-wind situation with the wind direction from the plant towards the receiving point. Fig. 4 shows the distribution of wind directions at the same turbine as previously described. It can be seen that the optimal direction in this case occurred during 10% of the total measuring time.

The graph in Fig. 5 shows the wind speed as function of time plotted together with the A-weighted sound level. The sound level is represented with the L_{90} metric, which is the best descriptor for the continuous sound from the wind turbine. This example is taken from a site relatively far from the wind turbine, 300 m. The measuring time in the diagram is 2 weeks with varying wind speed levels from 1 to 9 m/s. It can be seen that the correlation between the sound level and the wind speed at this particular site was relatively low. The explanation is that the wind turbine is probably not the dominant noise source.

Fig. 6 shows the frequency spectrum measured at different wind speeds from the same wind turbine. The distance to the plant in this example is 100 m. The result shows an increase in the high-frequency range at higher wind speed but also a low-frequency tone component at approximately 300 Hz.

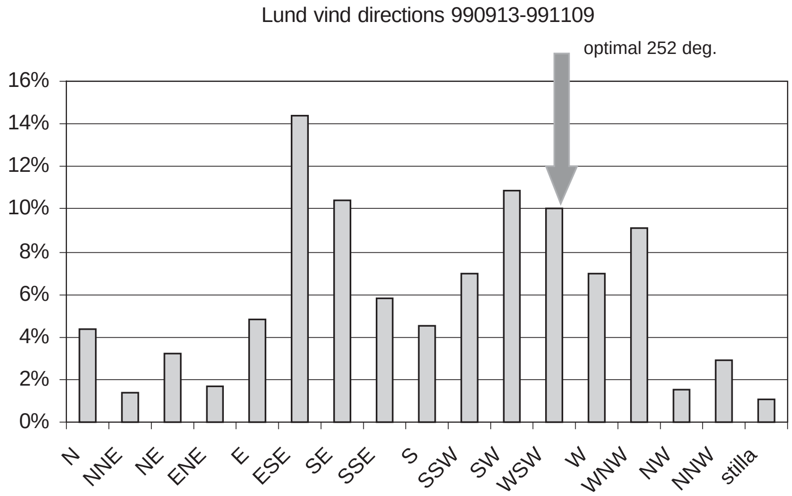

Fig. 4. Distribution of wind direction in degrees rel. N , percent of total measurement time.

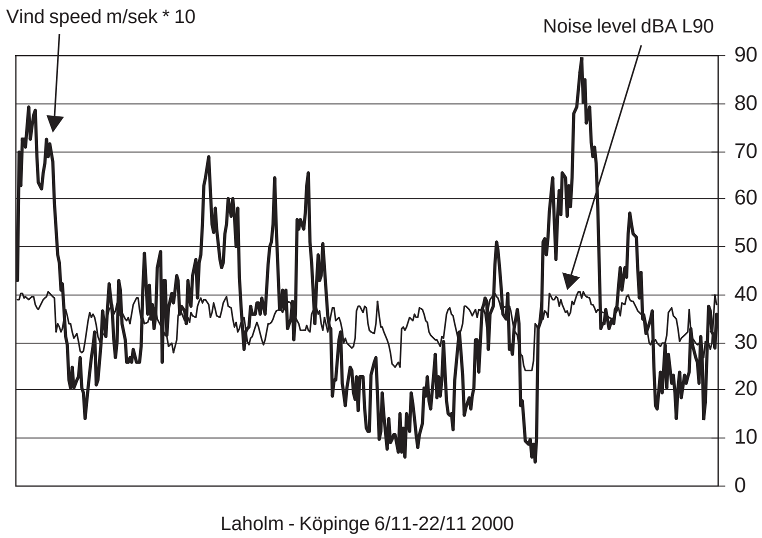

Fig. 5. Wind speed and noise level in dBA L_{90} versus time.

4. Conclusion

Large variations in meterological conditions and complex geographical relations make field measurements of the noise from wind turbines very time consuming. An automatic measuring station can be very helpful if measurements have to be performed at several sites. The results from field measurements undertaken with such a station showed that urban background noise level from sources such as road traffic often dominate at distances above 300 m from the wind turbine.

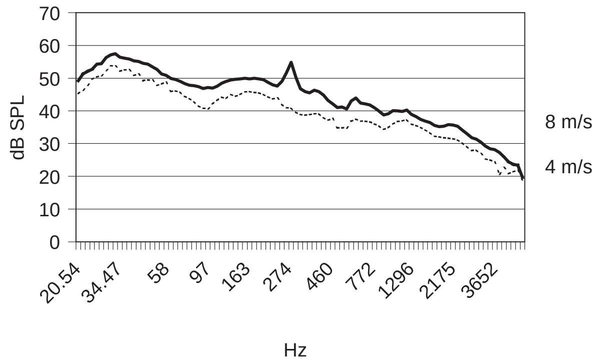

Fig. 6. Noise frequency spectra at wind speed 8 and 4 m/s, respectively.

The wind speed and operating condition of the wind turbine have complex influence on the soundscape and this is usually not described by the simple A-weighted noise indices [4,5]. Prediction models cannot always describe complex situations in a precise way and hence there is often a need for supplementary field measurements.

Acknowledgements

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